

Emerging Non-Volatile
Memory (NVM)
Technologies & Markets
2017

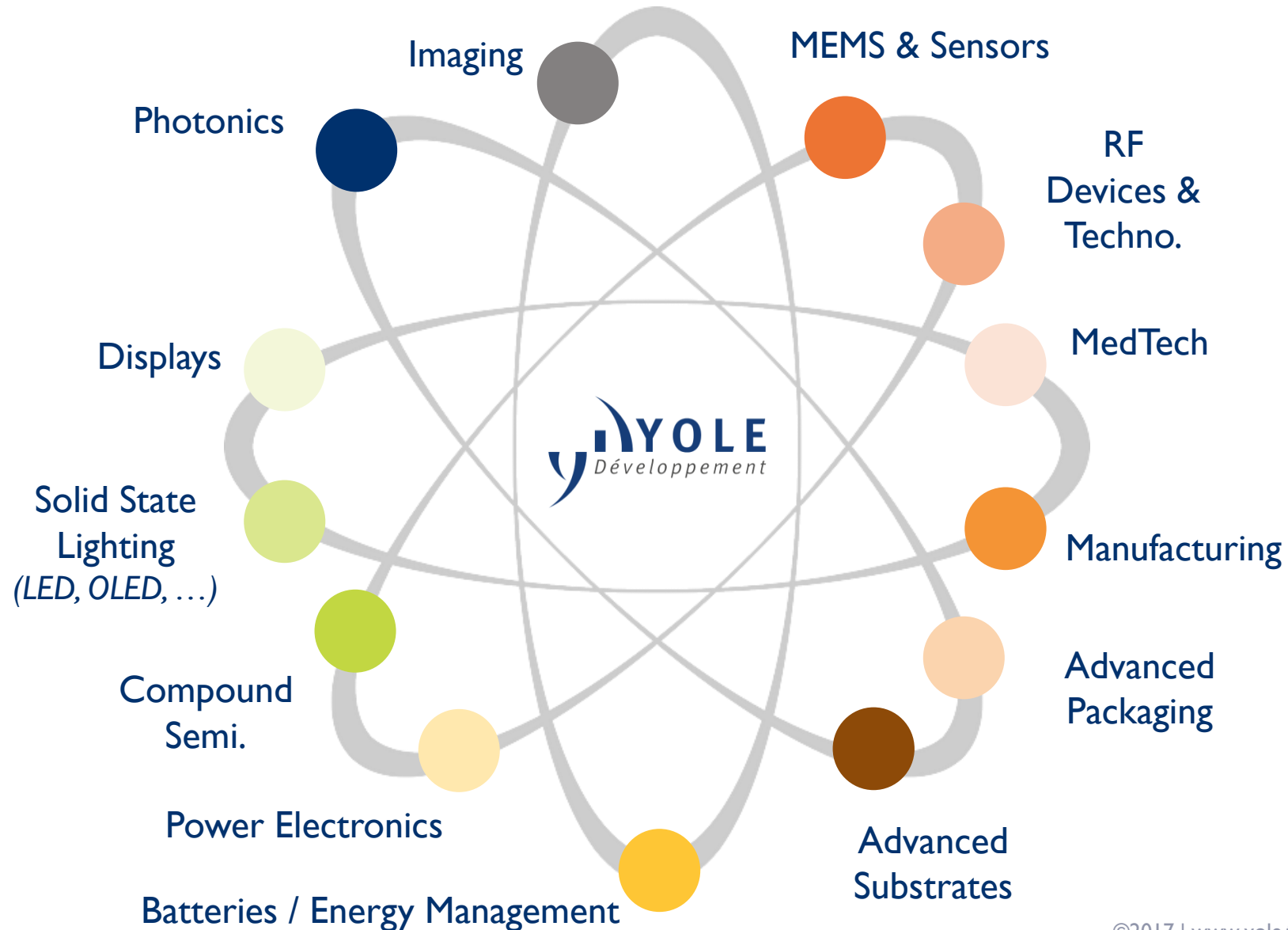
Leti Memory Workshop
June 27 Grenoble
Yann de Charentenay



- Introduction on Memory Market
 - Emerging NVM roadmap
 - Emerging NVM applications
 - Emerging NVM players
 - Conclusions
-
- The data and analysis of this presentation have been extracted from the following report published by YOLE Développement :
 - Emerging Non Volatile Memory Market & Technologies, June 2017

FIELDS OF EXPERTISE

Yole Développement's 30 analysts operate in the following areas





○ Consulting and Analysis

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- Technology analysis
- Strategy consulting
- Reverse engineering & costing
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- Teardowns & reverse costing analysis
- Cost simulation tool

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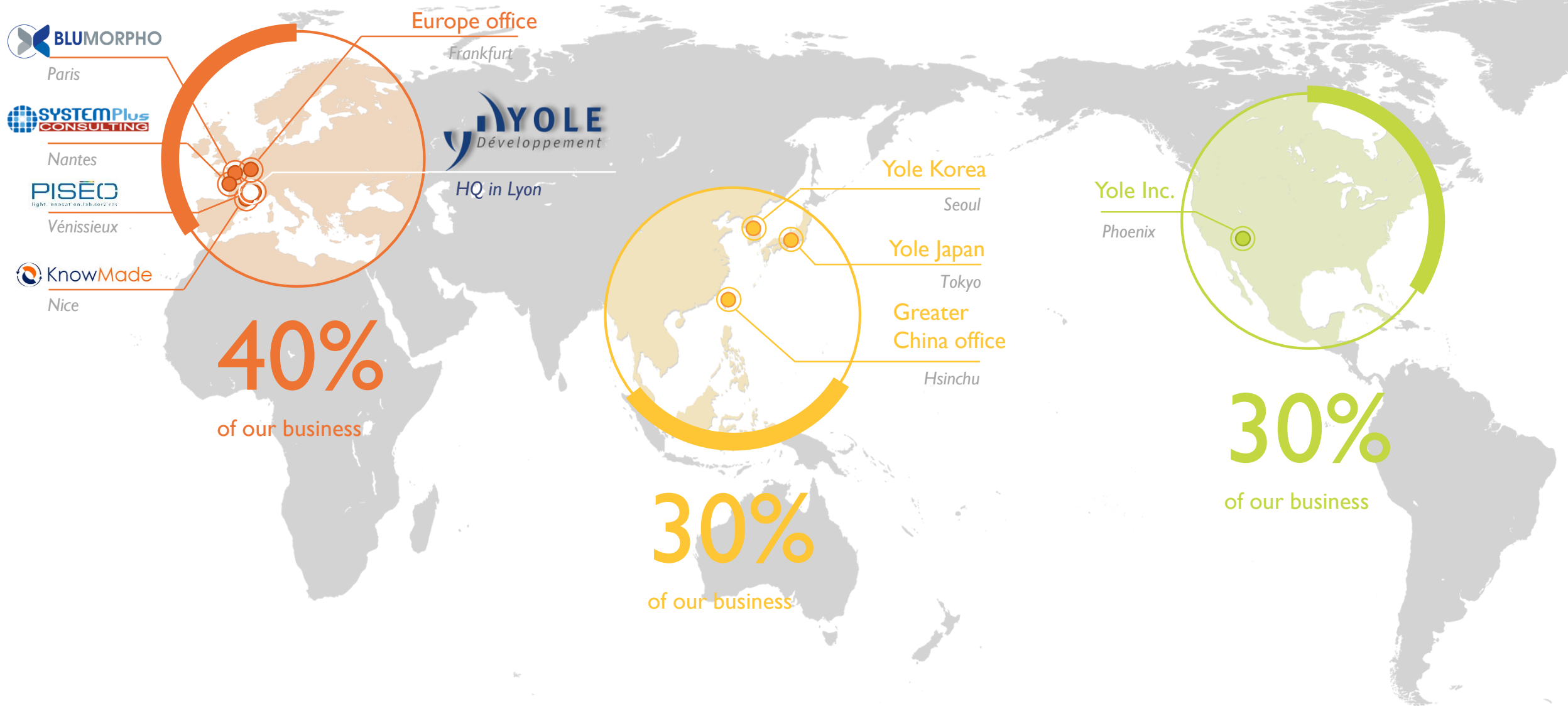
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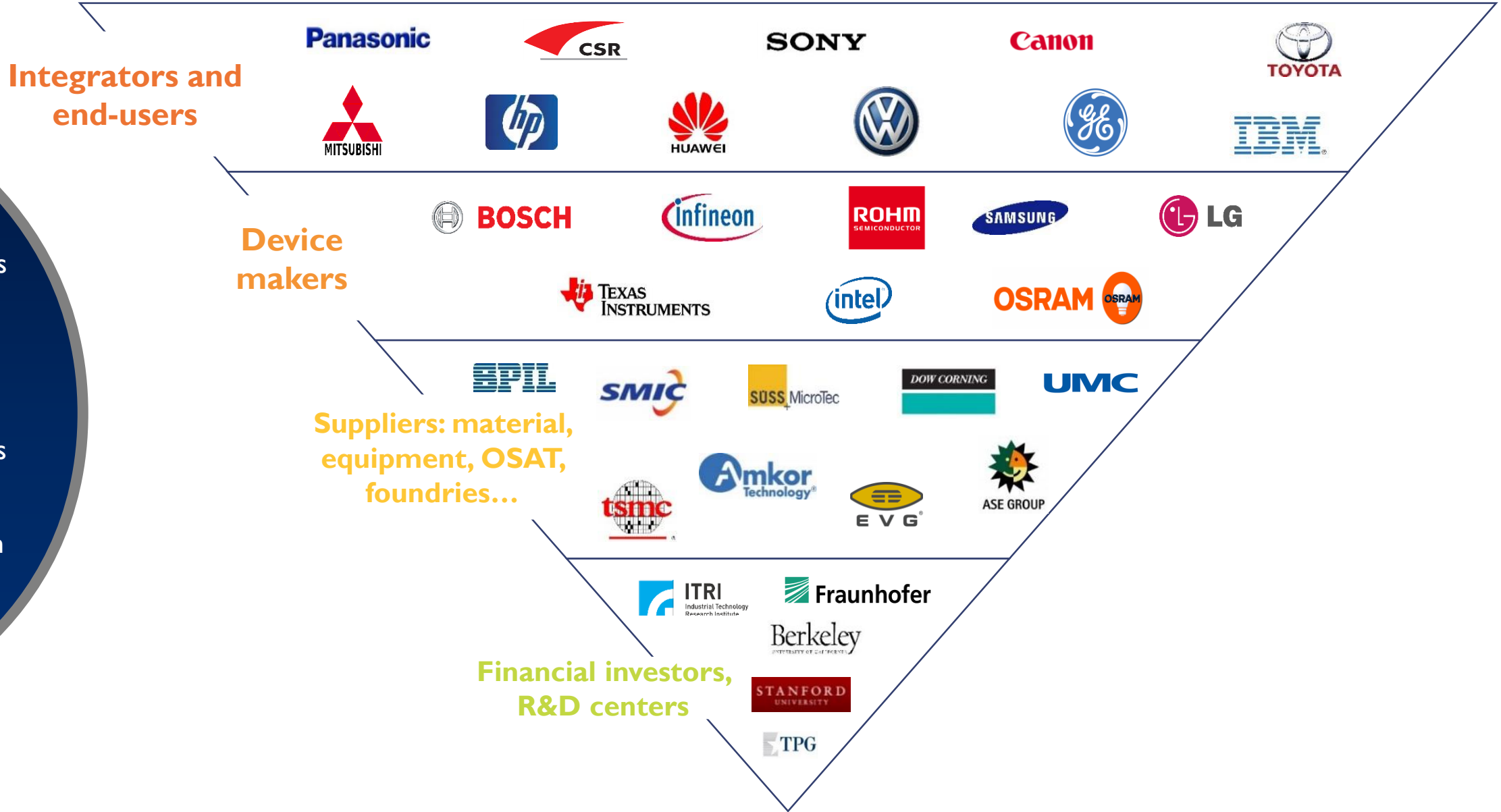
OUR GLOBAL ACTIVITY



SERVING THE ENTIRE SUPPLY CHAIN



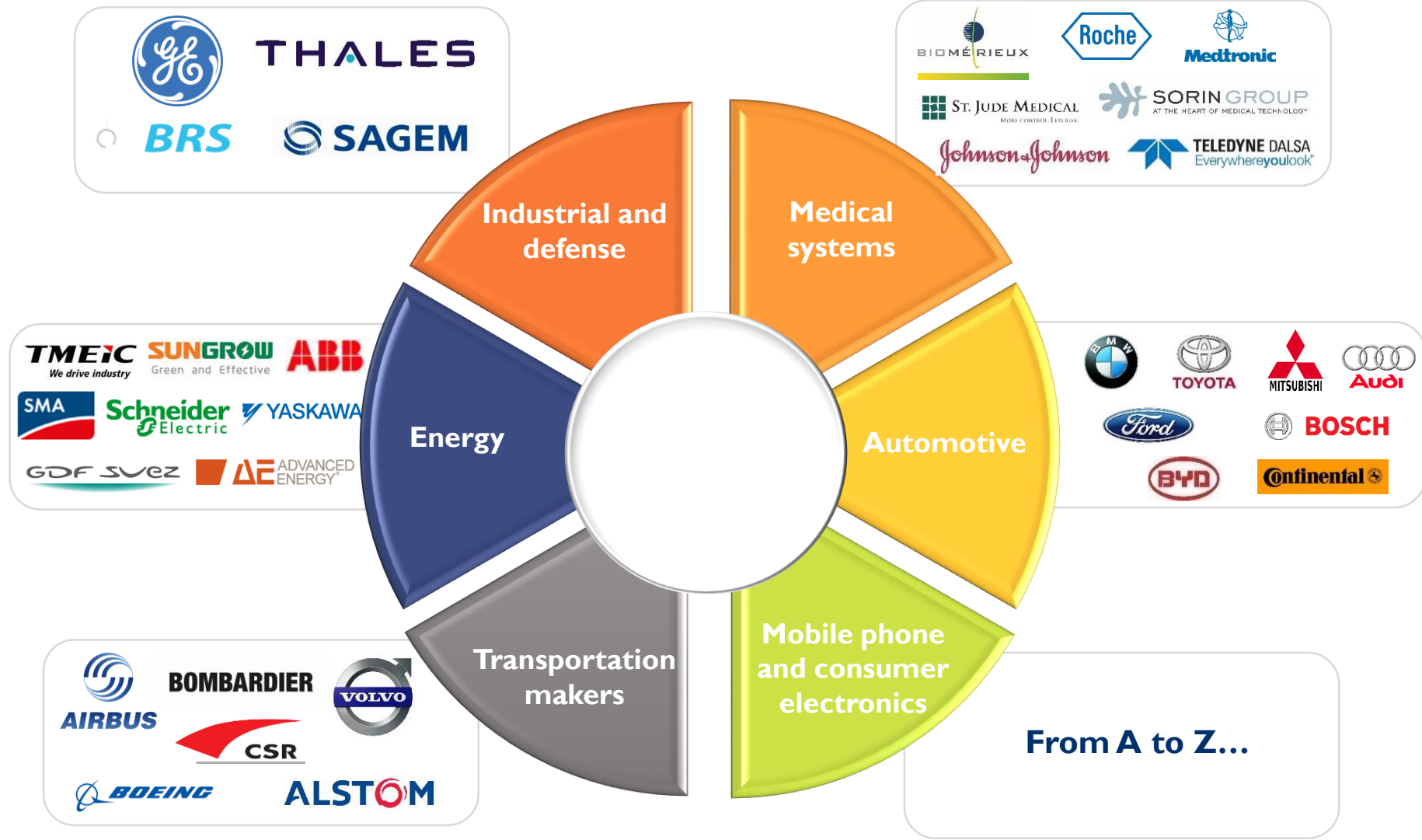
Our analysts provide market analysis, technology evaluation, and business plan along the entire supply chain

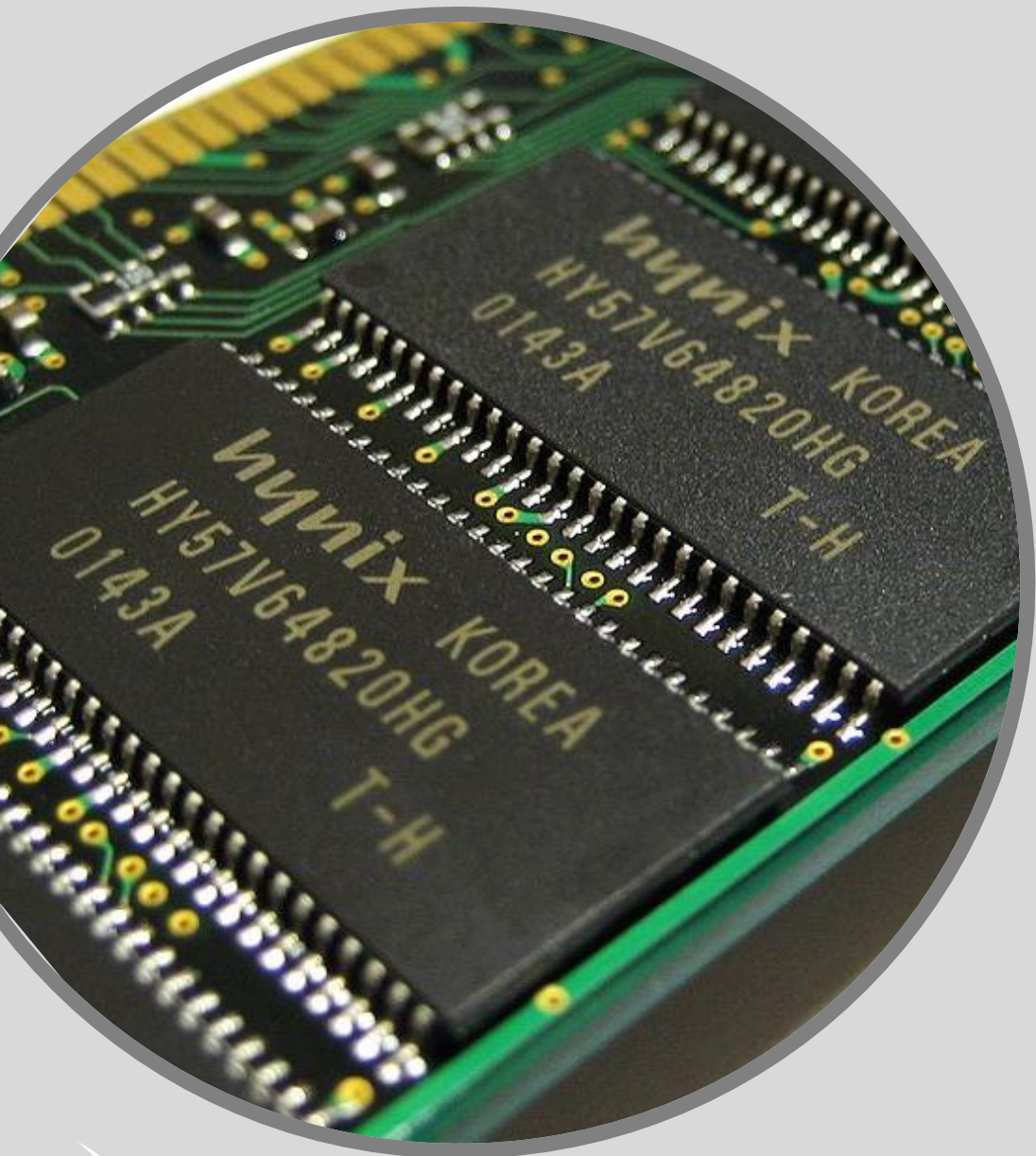


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We are working across multiples industries to understand the impact of More-than-Moore technologies from device to system





Standard memory market introduction

SOME DEFINITIONS

There are two types of memory business

- **Stand-Alone Memory:**

- Very concentrated market with 5 Integrated Device Manufacturers (IDMs) having 95 % of the total business.

- **Embedded Memory:**

- There are two types of embedded memory, depending on the level of system integration:

- System on Chip (SoC)

- Microcontroller (MCU), mobile Applications Processors (APU), high performance computing CPU
- Foundries are the key manufacturing players with 5 players having more than 80% of the total business.

- System in Package (SIP): A SIP is a number of integrated circuits enclosed in a single module (package).

=> manufactured by stand alone IDMs or integrators players.



MCU smart card chip



Multi Chip Package (MCP)

STAND ALONE VS EMBEDDED MEMORY BUSINESSES

- Very different businesses !

	Stand alone memory	Embedded memory
Density	Few Gb – Few 100 Gb	few Mb - few 100's Mb
Technological node	< 20 nm	28 – 90 nm
Price	< \$ 1 /Gb	> \$ 10 / Gb
Incumbent technologies	NAND DRAM	Eflash NOR SRAM
Key players	IDM's : Samsung, Micron, Sky Hynix, Toshiba, WD Sandisk	Foundries : TSMC, GF, UMC, SMIC, Samsung

- Embedded SoC applications are technically and economically more accessible for emerging NVM => good starting point !
- Main potential emerging NVM embedded markets : microcontrollers (MCU), applications processors (AP), high performance computing CPU.
- In the future, thanks to its CMOS compatibility and good scalability, emerging NVM will enable embedded memory to take market share to stand alone memory.

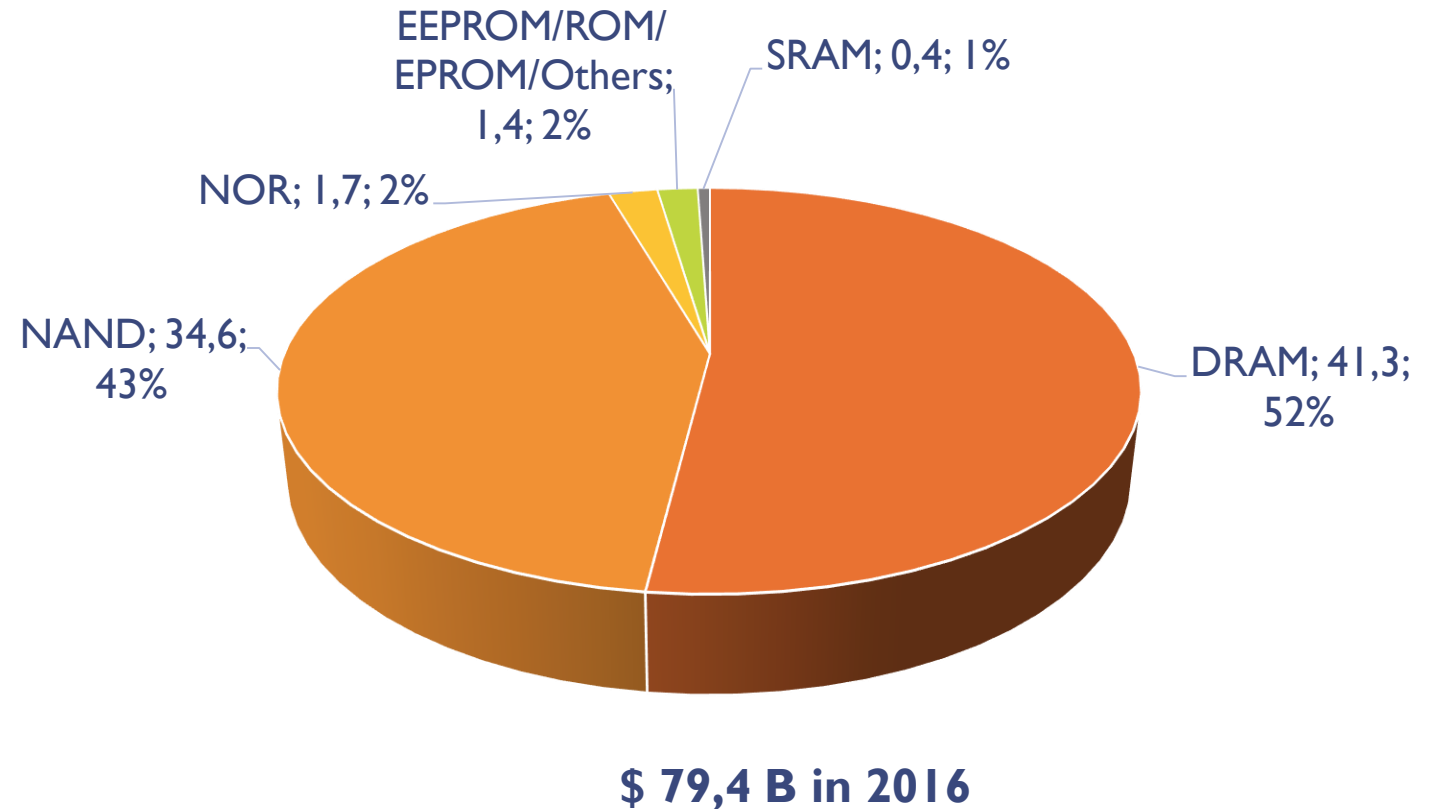


Stand-alone memory market revenue evolution:

- \$78B in 2014: CAGR = + 17%
- \$80B in 2015 : CAGR ~ +2 %
- \$79.4B in 2016: CAGR ~ - 1% due to price erosion

NAND and DRAM dominate the stand-alone memory market, representing 95 % of stand alone memory sales.

Semiconductor memory market 2016



EMBEDDED MEMORY - MARKET SIZE

Embedded memory is a submarket of the MCU and MPU markets. It is generally not estimated because it is not a stand-alone market.

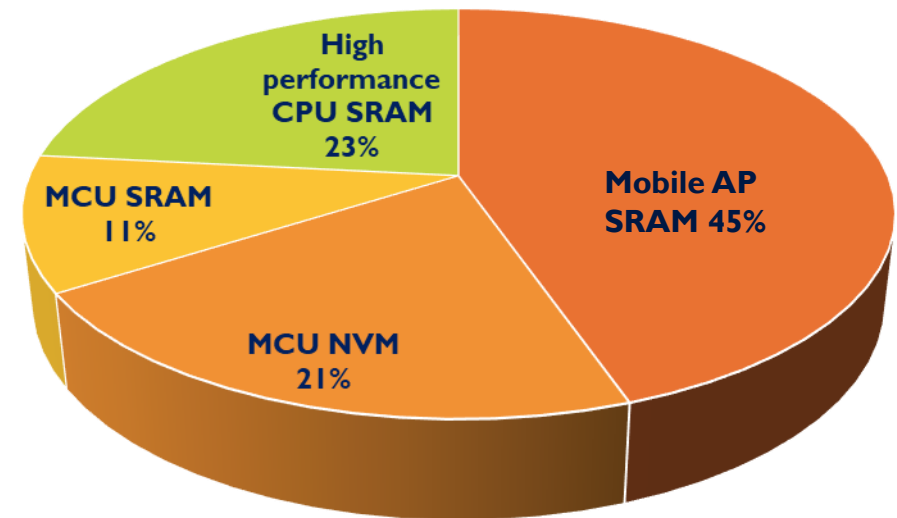
However, we know that memory represents about 45% of MCU cost and 50% of mobile MPU surface. This ratio allows us to roughly quantify the embedded memory business:

- **MCU memory business:**
 - NVM: \$5.3B, equal to 30% of MCU cost
 - SRAM: \$2.6B, equal to 15% of MCU cost
- **Mobile AP memory business:**
 - SRAM = \$11B, equal to 50% of MPU cost
- **High performance CPU memory business**
 - SRAM= \$5.7, equal to 50% of CPU cost

Total 2016 embedded memory ~ \$24.6B. This represents 31% of the stand-alone memory business. That's a big number!

In the long-term, emerging NVM could also replace SRAM in the general CPU business. This would double the embedded memory business!

2016 Embedded Memory Market
Market in 2016 ~ \$24.6B



Yole Développement © July 2017



- Process scaling reduces the cost by decreasing the cell size and thus the chip size.
- Process scaling reduces power by lowering operating voltage.
- Process scaling combined with the right interface increases bandwidth.

TRADITIONAL MEMORY ROADMAP

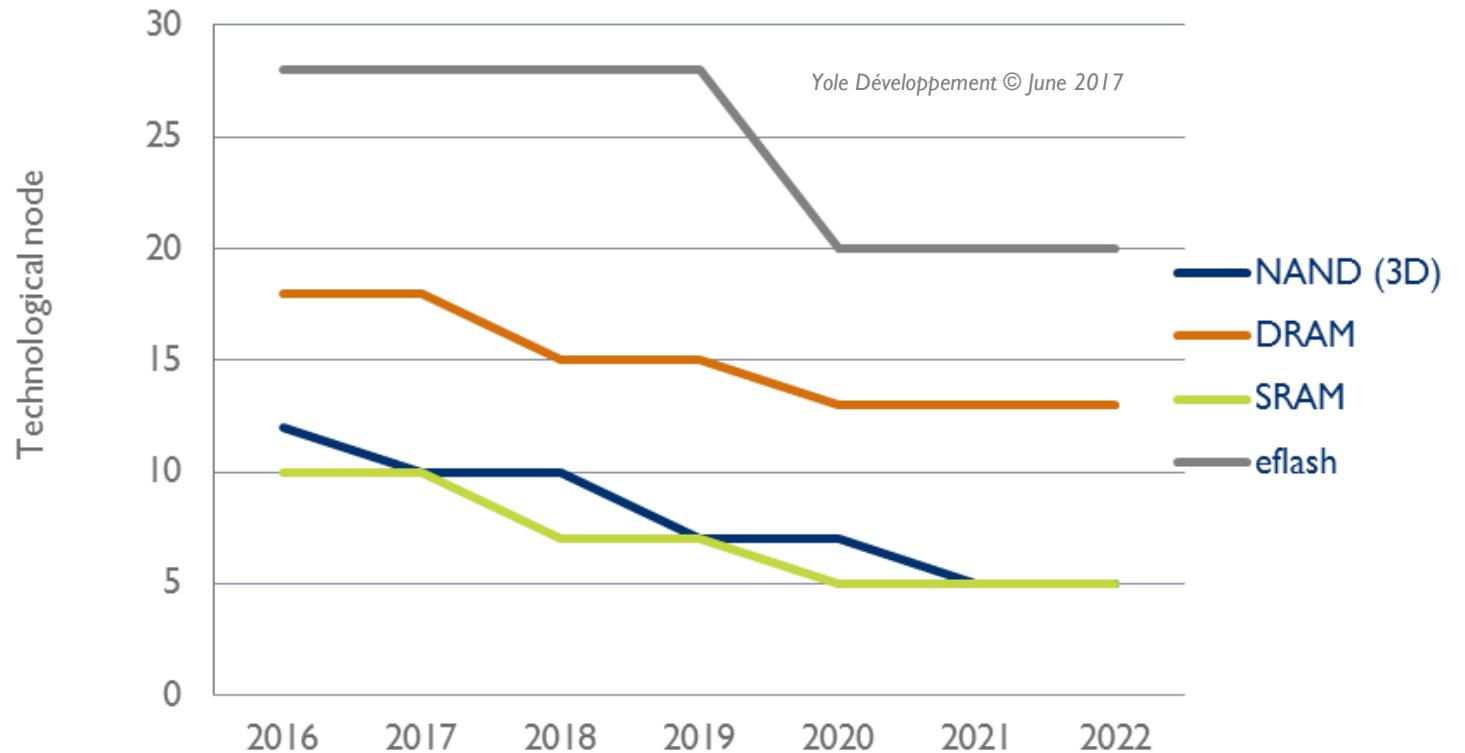
Stand-alone and embedded memory

Stand-alone memory, NAND, and DRAM scaling are slowing down in terms of technological node. However, the 3D approach will allow increased bit density for NAND.

Embedded memory :

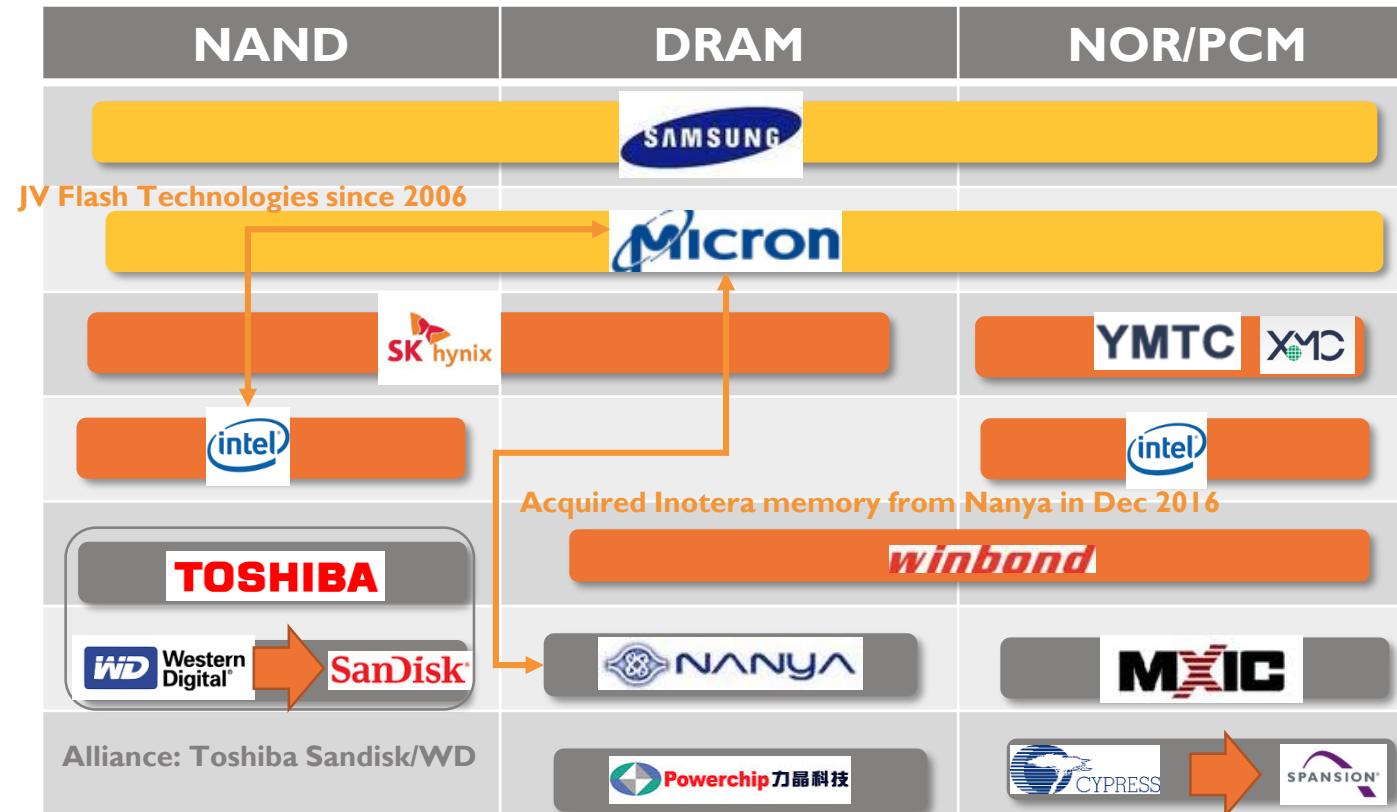
- eflash scalability is low and limited by rising cost.
- SRAM scalability is already very high and challenging for a new memory introduction

Main traditional memory roadmap



STAND-ALONE MEMORY - SUPPLY CHAIN

Key market players



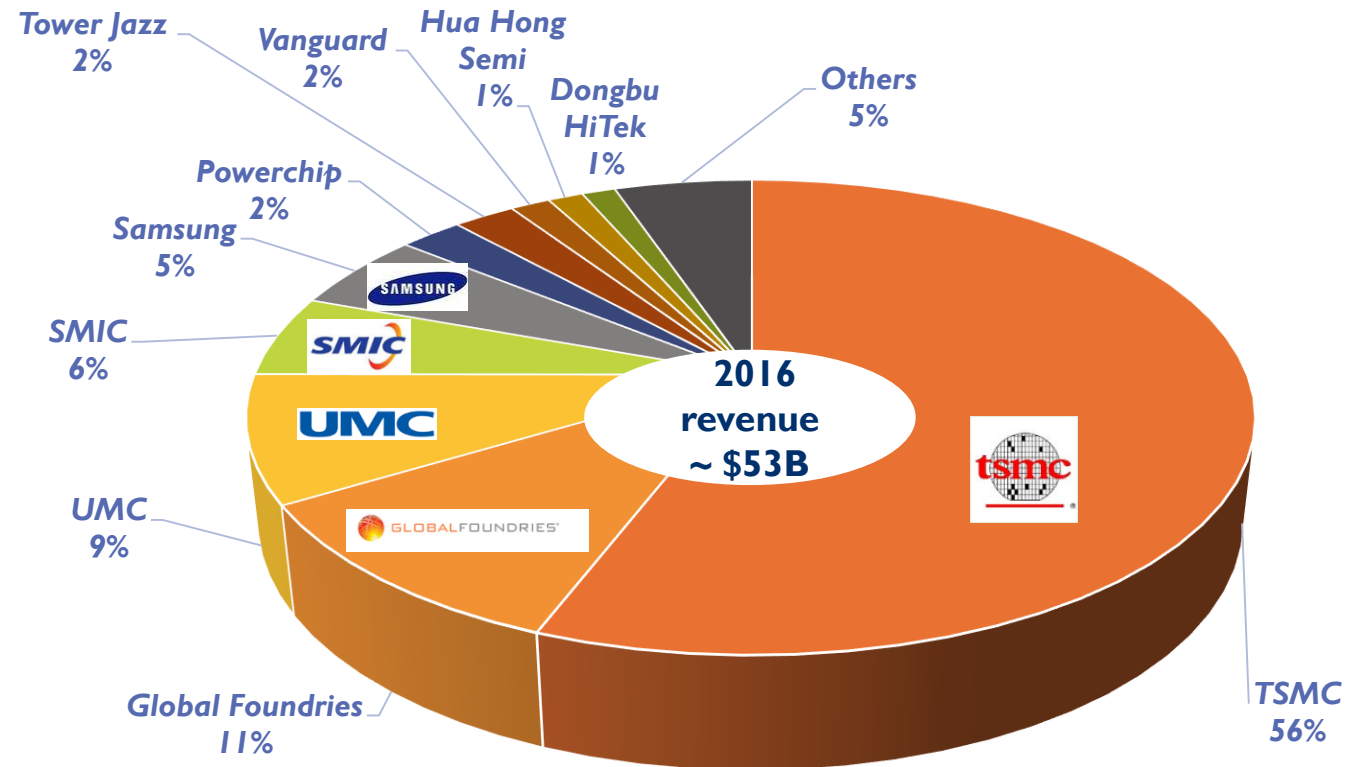
Market concentration has increased over the last few years : 5 players owns 95% of the business

- Samsung, Micron, SK Hynix, Toshiba and Western Digital – Sandisk are dominating the business
- Toshiba is selling off its NAND memory business => Big change in the competitive landscape ! Who will win ?
 - Current players : SK Hynix, Micron, WD.. ?
 - Or new players : Foxconn, Apple, Google, Broadcom ?

FOUNDRIES : KEY EMBEDDED MEMORY PLAYERS



- Semiconductor foundries are primarily focused on logic businesses, and are rarely involved in the stand-alone memory business (except Powerchip with DRAM and Fujitsu with FRAM).
- These players are manufacturing most of embedded memory for MCU and AP businesses, and could show future interest in the stand-alone business.
- TSMC is very dominant on this business and its emerging NVM technological choice will have a huge impact on embedded emerging NVM market !



Pure play foundry market share by revenue (2016)

Foundries are the key players for embedded memory businesses

CHINA MEMORY LANDSCAPE

China represent 40 % of world memory consumption...who will produce the chips in the future??

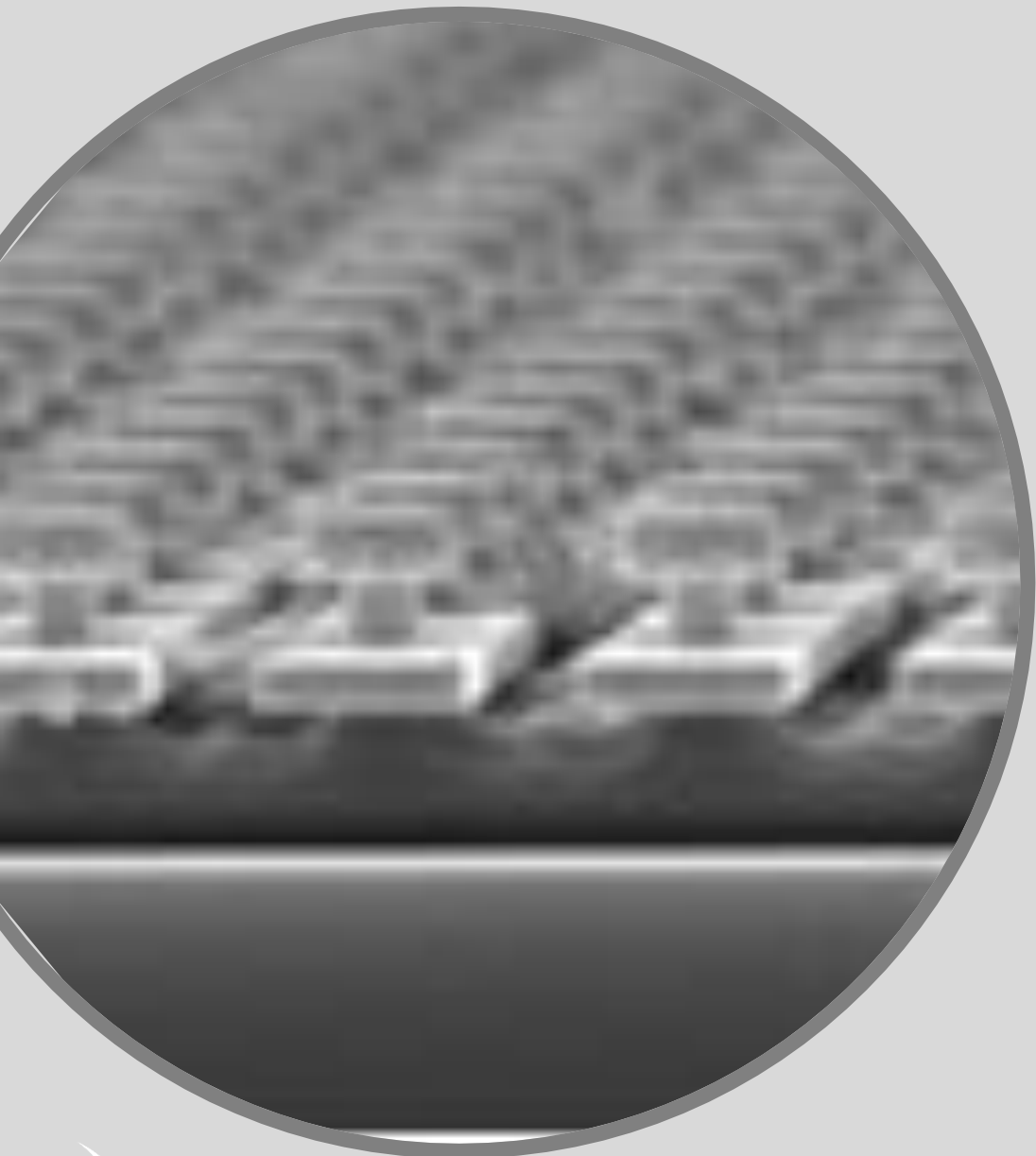
Tsinghua group which acquired XMC in 2017 is leading the effort to develop memory local supply chain



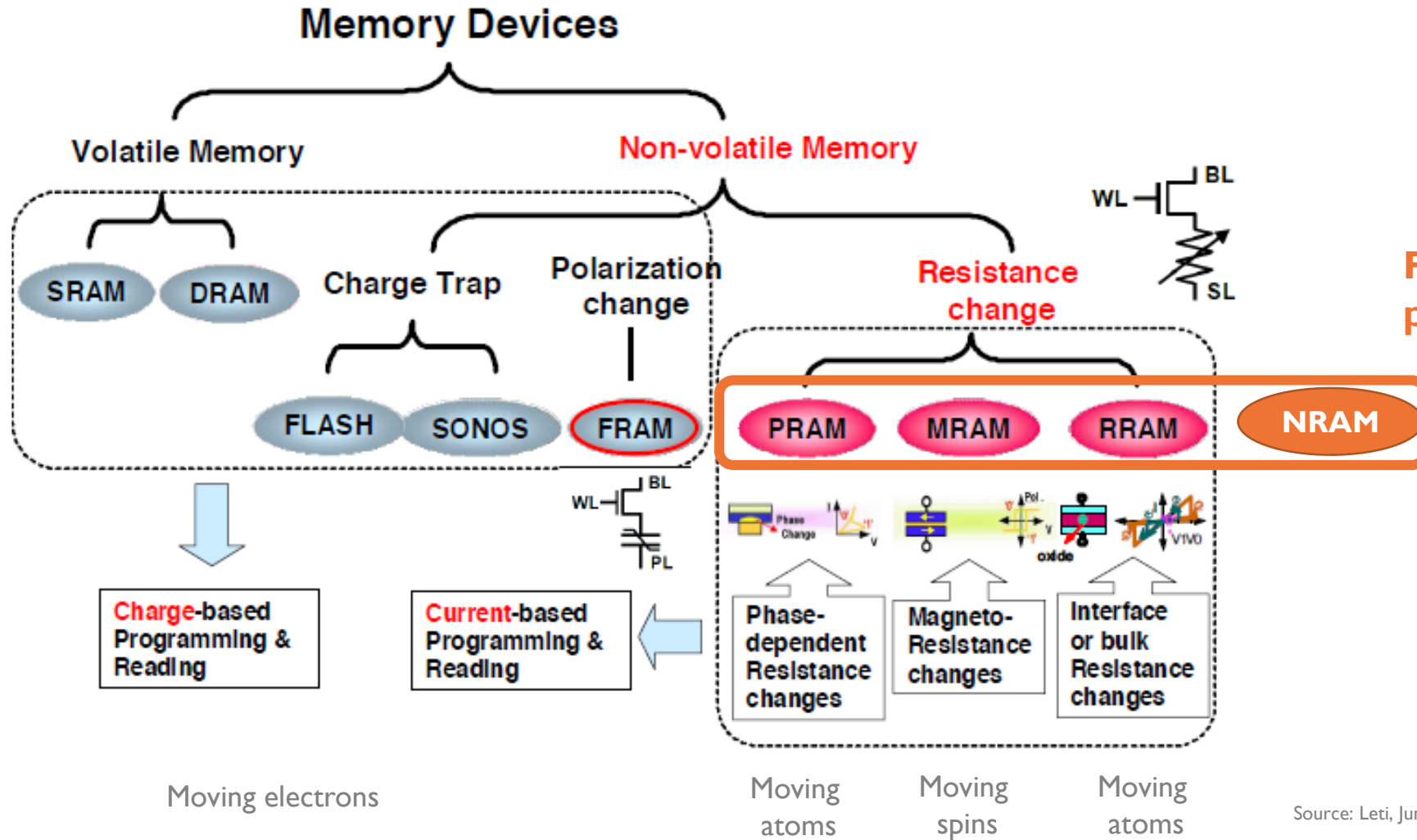
- Some foreign memory makers are already presents in China : Samsung, SK Hynix, Intel.
- And number of local players is growing : Tsinghua group / XMC, Fujian Jinhua Integrated Circuit Co. foundries SMIC and HH Grace & HLMC, GigaDevice fabless partnering with Hefei City government to form Hefei ChangXin.

Main market trends

- Stand-alone memory business (NAND and DRAM) is the largest memory market:
 - NAND and DRAM markets will grow rapidly, pushed by the growing need for memory in mobile devices and enterprise storage
 - NAND and DRAM scalability was supposed to reach its limit in 2020, but engineers have finally found new solutions, just like in the past, to exceed this limit:
 - => emerging memory technologies must “catch a running train” with huge annual R&D investments (several \$B) in existing DRAM and NAND technologies! Right now, big memory makers consider emerging NVM more of a “nice have” than a “must have”.
- Embedded business is dependent on the end-market (MCU or mobile AP)
 - Today, the MCU market is growing and is less stringent in terms of scalability. However, eflash will become cost prohibitive at 28 nm in many applications. Emerging NVM is “a must have” in order to differentiate from competitors => strategic technology in the short-term.
 - Mobile AP uses leading-edge node (14 nm) for logic and SRAM. Thus, it will take longer time to replace it (2019-2020).



Emerging NVM Roadmap



Focus of this presentation

Market status

Various factors contributed to delay of adoption of emerging NVM on large scale.

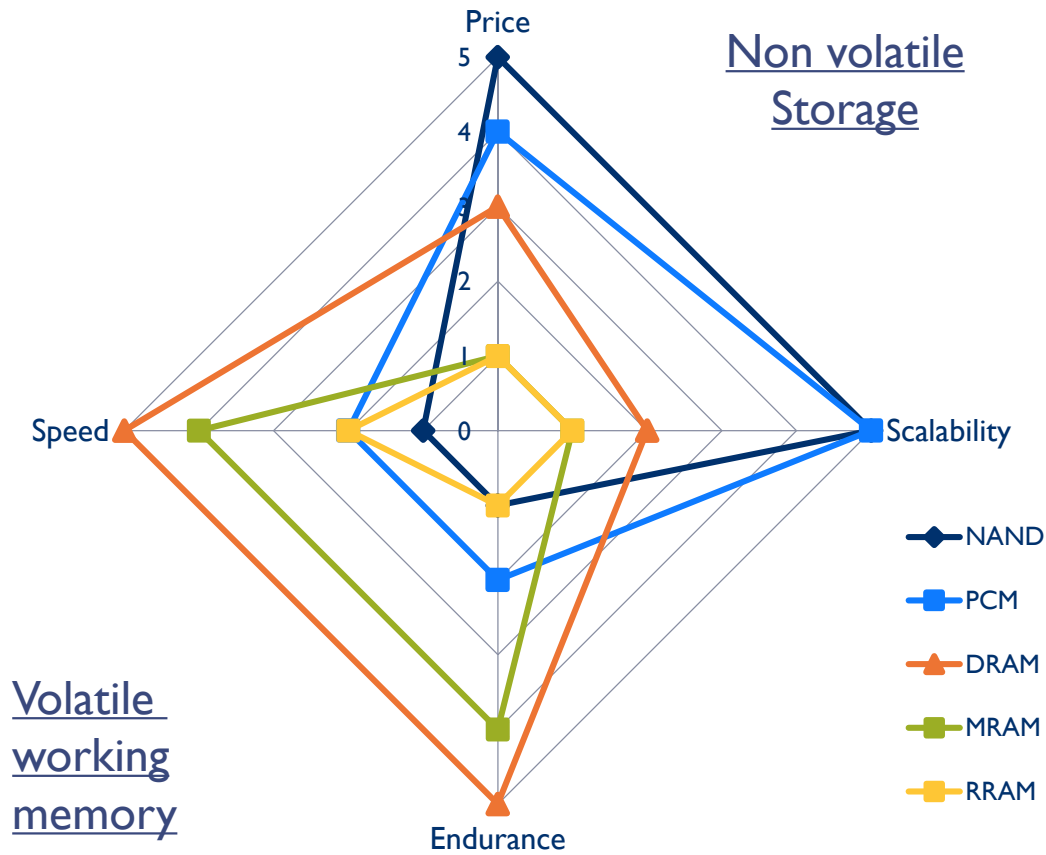
Why emerging NVM strong market adoption keep delaying UNTIL NOW despite showing great potential ?

- *Limited density product availability*
- *High density products introduction delayed by emerging NVM pioneers: Intel/Micron delayed introduction of PCM based memory.*
- *Technical challenges due to introduction of new materials and process steps.*
- *Big logic foundries (e.g TSMC, Samsung, Global Foundries) non involvement in emerging NVM business for embedded application*
- *Big memory players (Samsung, Micron, SK/Hynix/Toshiba) abandon or postpone introduction of emerging NVM for stand alone products in order to not cannibalize their existing business.*
- *Mainstream memories DRAM & NAND continued scalability improvement (higher performance at low cost) => catching a running train*
- *No key emerging application that would substitute DRAM & NAND*

STAND-ALONE MEMORY - 2017 POSITION

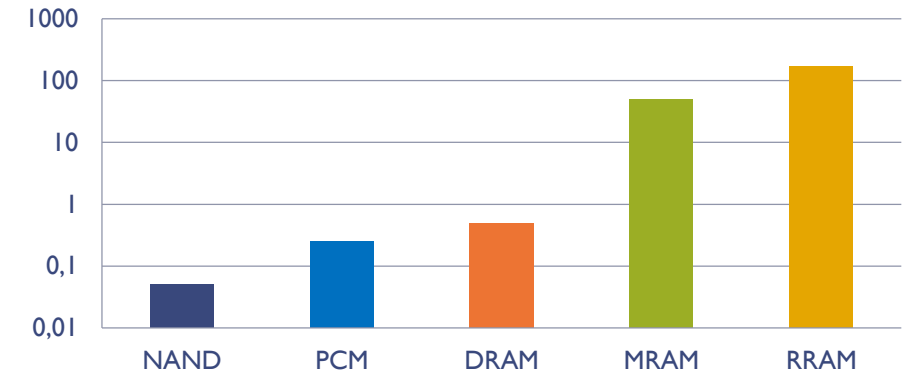
Commercial products performance

Price and scalability are obstacles for emerging NVM to compete with DRAM and NAND

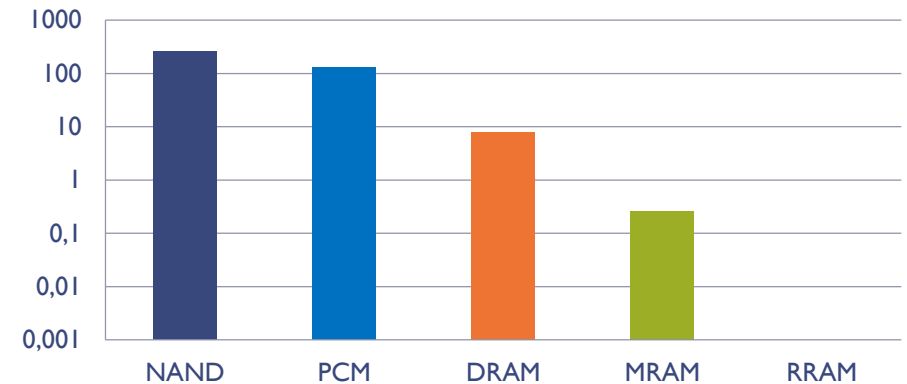


5 : best value
0 : worst value

Memory pricing position in 2017 (\$/Gb)



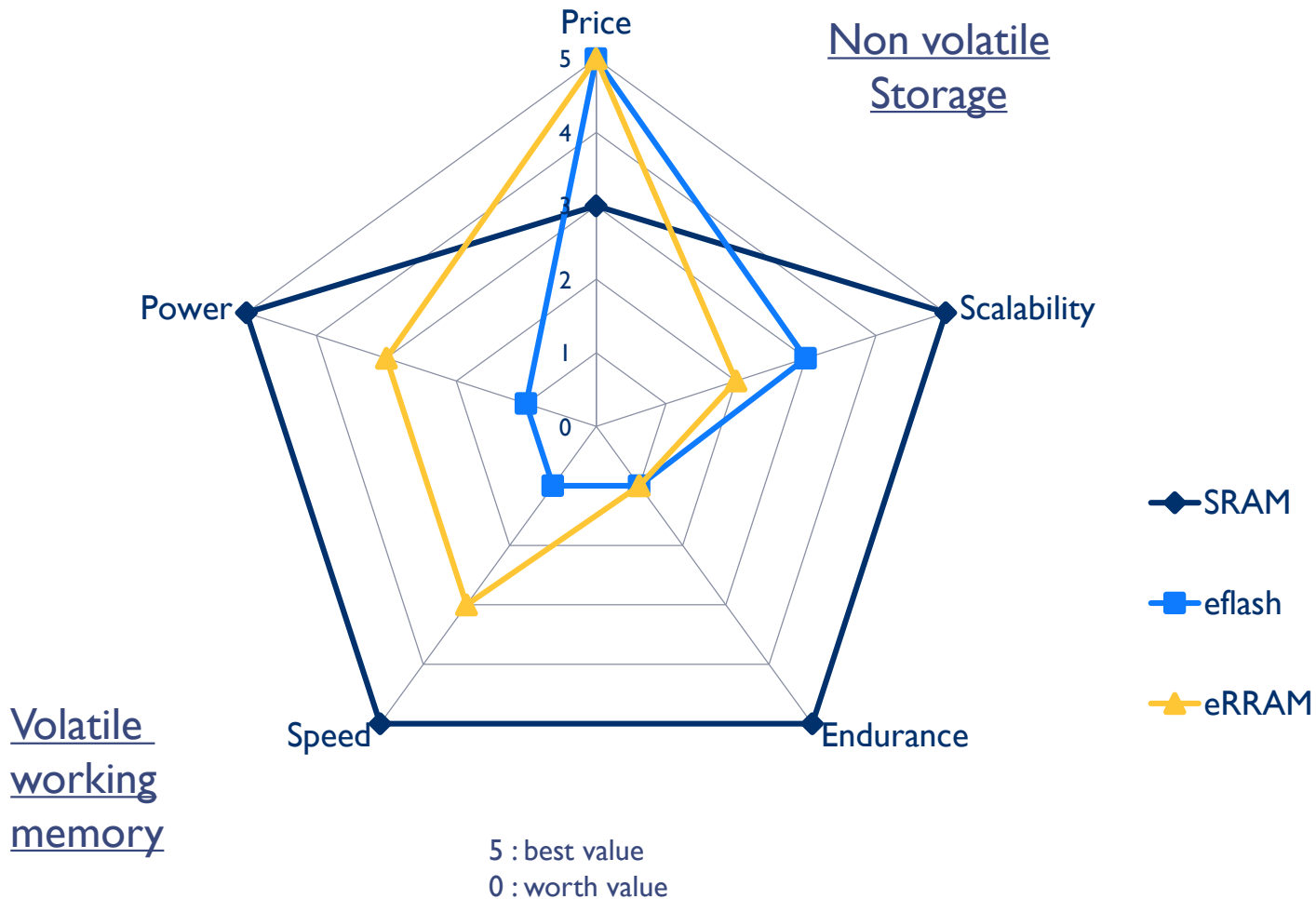
Density position in 2017 (Gb)



EMBEDDED MEMORY - 2017 POSITION

Commercial products performance

eRRAM is now close or better than eflash but SRAM is still far away



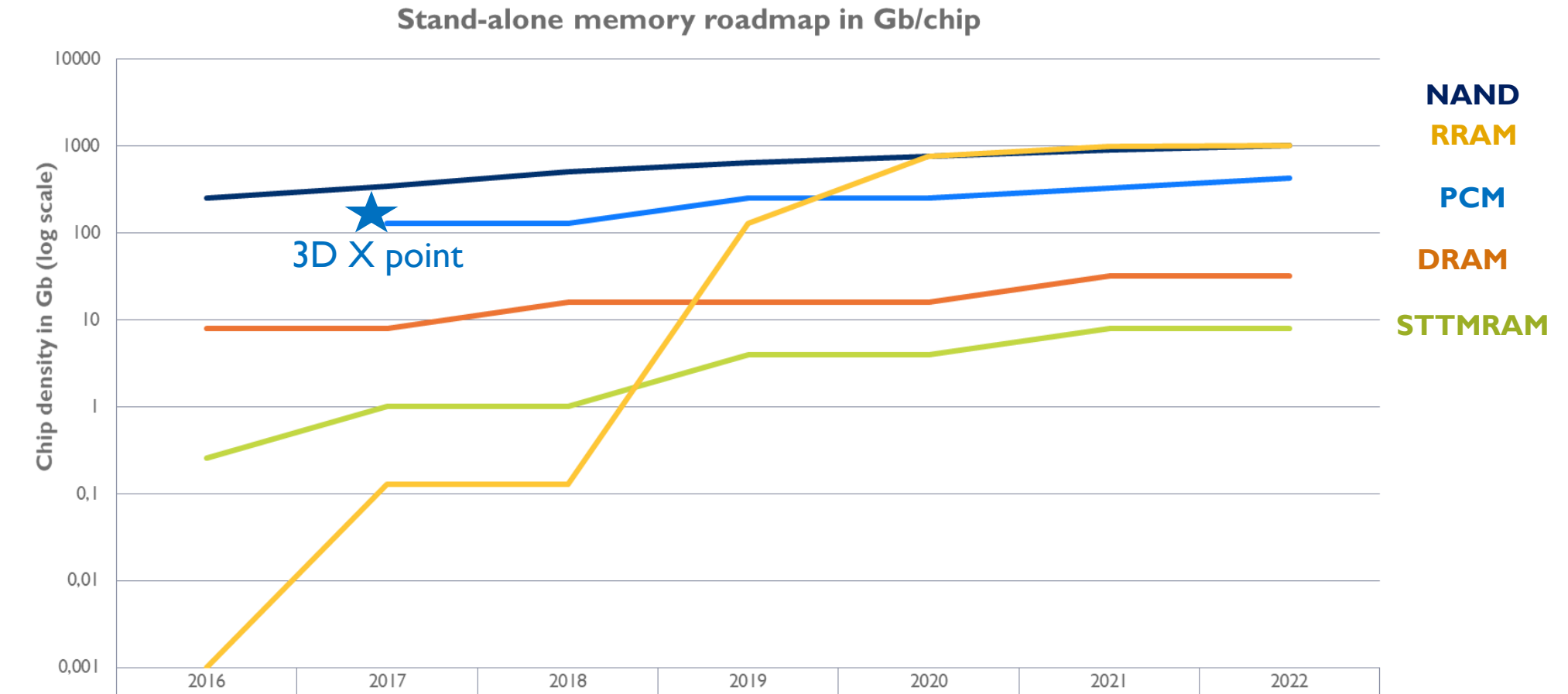
RRAM 40nm SMIC crossbar wafer

- ◆ SRAM
- eflash
- ▲ eRRAM

EMERGING NVM + DRAM AND FLASH NAND

Maximum chip density roadmap (stand-alone devices)

3D XPoint is the first commercial emerging NVM with such high density, but speed is far below DRAM => SCM application



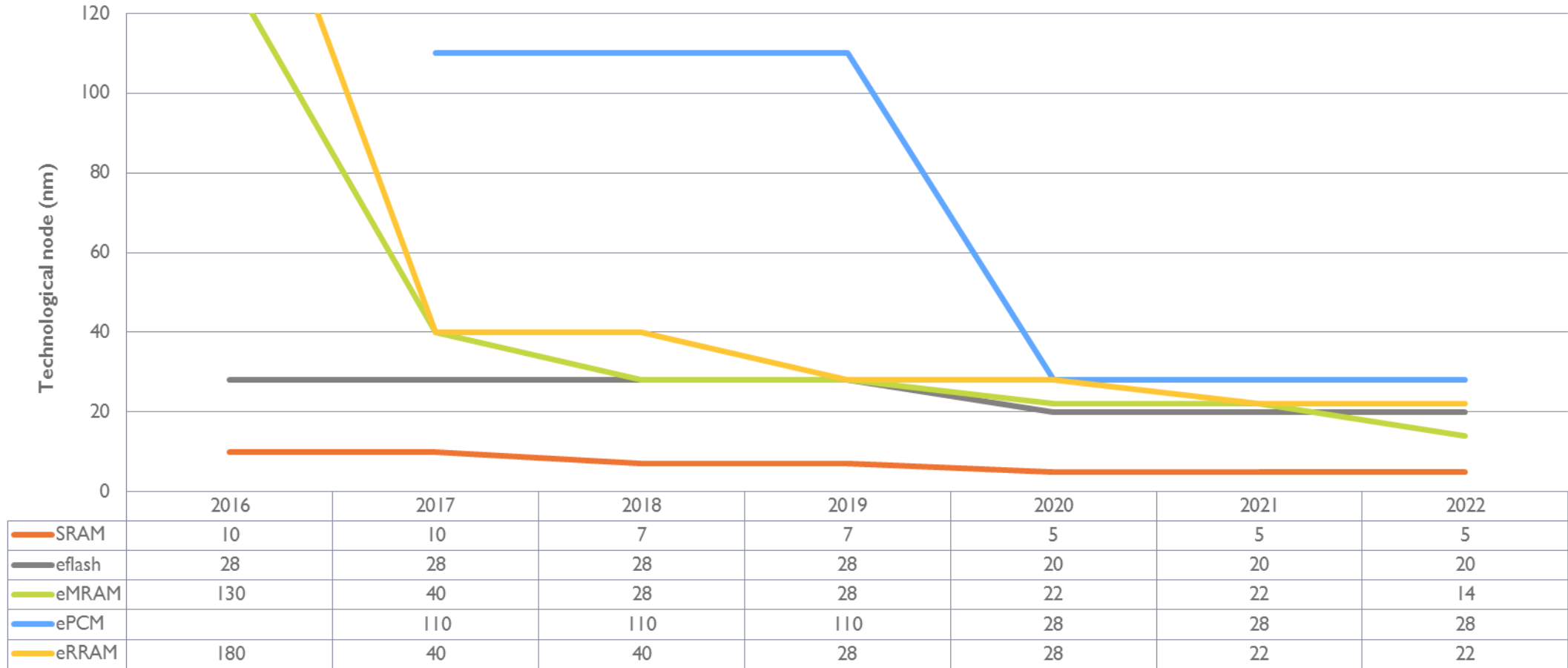
EMERGING NVM - ROADMAP

Embedded SoC devices



Convergence between emerging NVM and eflash is expected to happen at the 28 nm node around 2018. SRAM substitution is expected after 2020 by MRAM only

Embedded SoC memory roadmap





Emerging NVM applications

EMERGING NVM - APPLICATIONS



Stand alone

Emerging NVM Applications

Embedded

Industry & Transportation & consumer electronics

Enterprise Storage

Client SCM

Mass Storage Memory

Micro Controllers (MCUs)

Mobile Devices SRAM

Embedded L3 cache SRAM high performance

Embedded NVM SoC



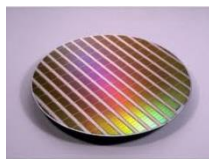
Industrial Automation



Journal Memory



Work Station



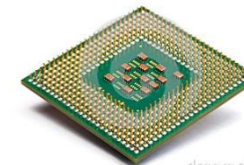
NAND Memory



IoT



Smartphones & Tablets



dreamstime.com



Smart Meter



Storage-Class Memory (SCM)



Notebook



Smart card



General Purpose



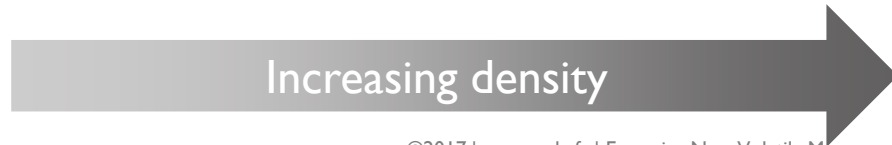
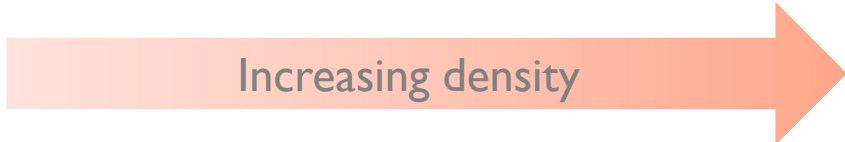
Automotive



Volatile DRAM



Automotive

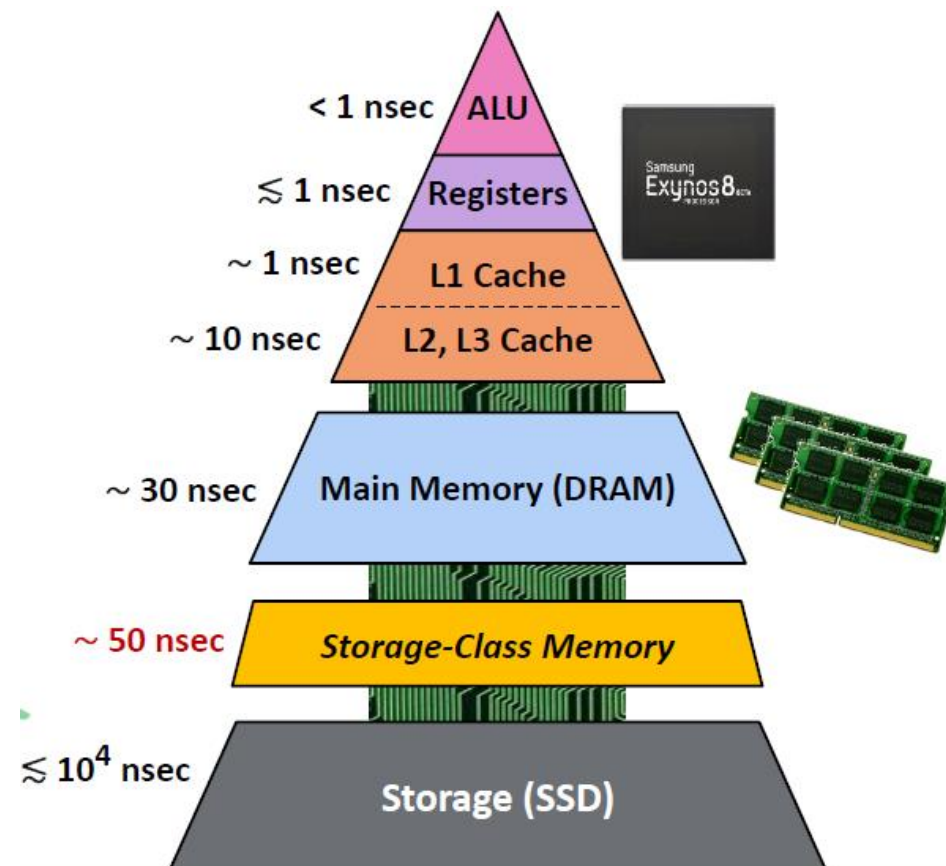


STORAGE-CLASS MEMORY (SCM)

A new tier in the stand alone memory hierarchy

- The near-term goal for emerging NVM is to become a new memory type in the system architecture: storage-class memory (SCM)
- SCM is IBM's term for a new class of data storage and memory device : in-between working memory and data storage, to reduce latency, i.e. increase system speed.
- Indeed, there is still a big latency gap between DRAM and NAND SSDs (a 100x – 1000x difference)

SCM is the big target for emerging NVM in stand alone applications



Source: IMV, Samsung, May 2016

EMERGING NVM - APPLICATIONS POSITIONING

SCM definition

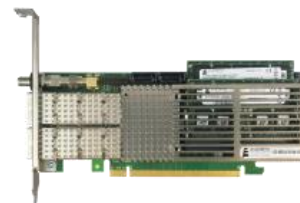
SCM's definition is not yet standardized, and there is still uncertainty about its specifications. However, it has already been further refined into two sub-segments:

- Memory type SCM M: this memory corresponds to DRAM and STTMRAM characteristics. Very fast with high endurance. Few-Gb density expected.
- Storage type SCM S: this memory corresponds to RRAM or PCM – 3D Xpoint characteristics. It is closer to NAND with higher endurance and speed, and at a lower cost than SCM M.

	SCM M		SCM S	
	DRAM	Memory Mapped	Storage Mapped	NAND
Latency	1x	2x	10x	1,000x
Endurance	$\sim 10^{15}$	$\sim 10^{13}$	$\sim 10^7$	$\sim 10^3$
Non-Volatile	No	No	Yes	Yes
Cost	DRAM	\sim DRAM	$\sim 0.2x$ DRAM	NAND

Source: Micron, June 2014

STTMRAM



Everspin accelerator
1,5 M IOPS

3DXpoint
RRAM

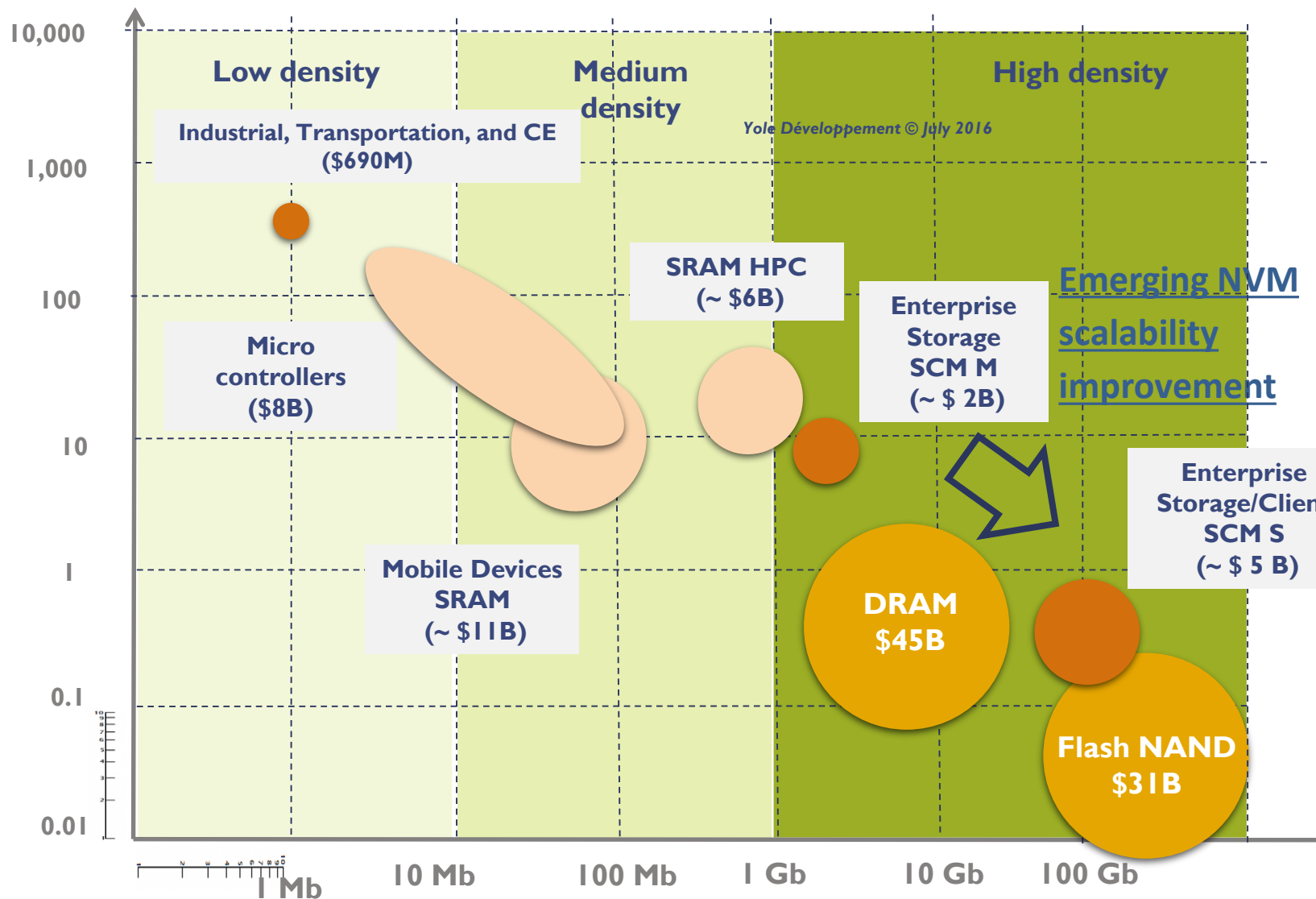


Intel Optane M.2
250 – 200 K IOPS read

EMERGING MEMORY - POTENTIAL APPLICATIONS

Density and price positioning

Price per Gbit
(\$/Gb)



Bubble size corresponds to TAM market size in 2016

Emerging NVM scalability improvement

Chip maximum density

With emerging NVM scalability improvement, mainstream applications targeted by DRAM and NAND will be accessible

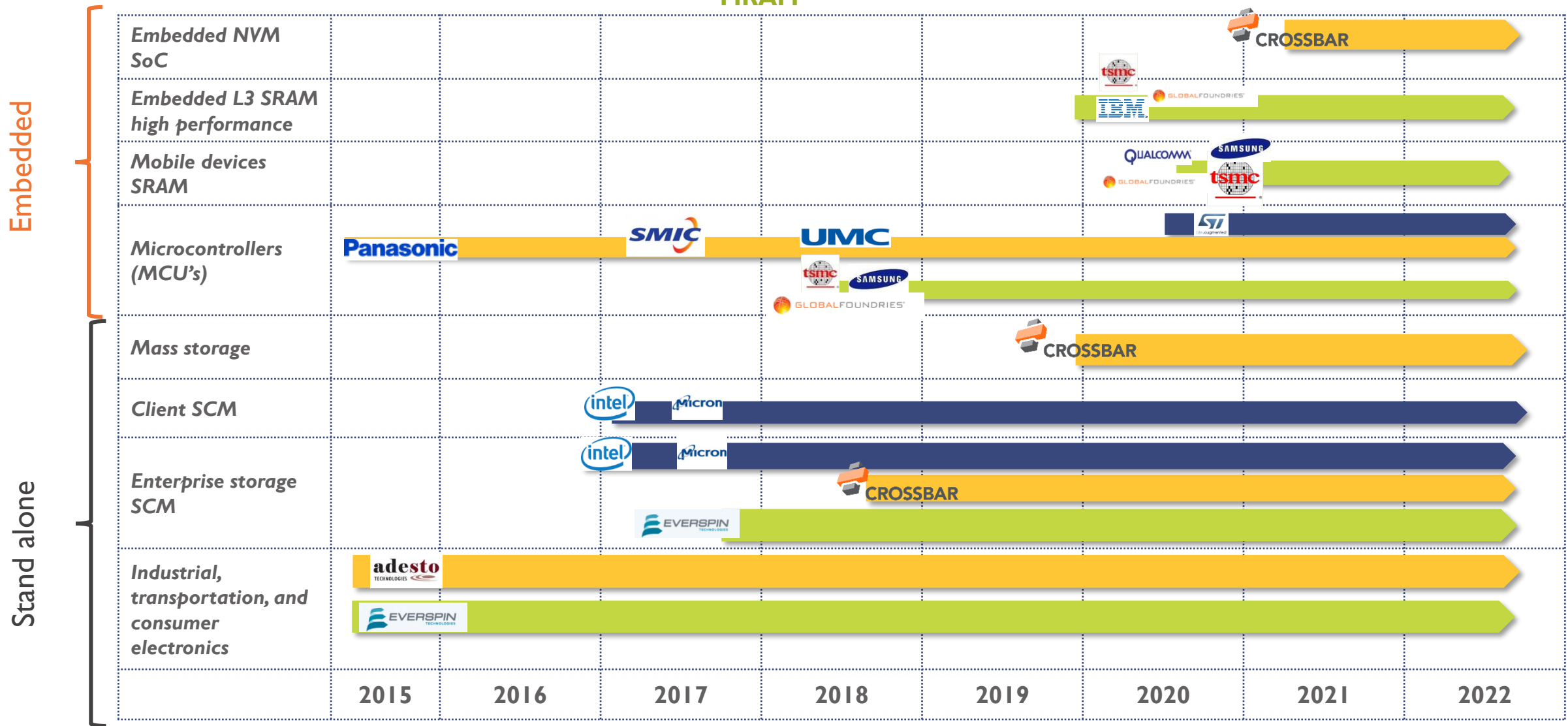
EMERGING NVM – TIME-TO-MARKET

By application and with first players

◆ MRAM/STT MRAM

◆ PCM

◆ RRAM



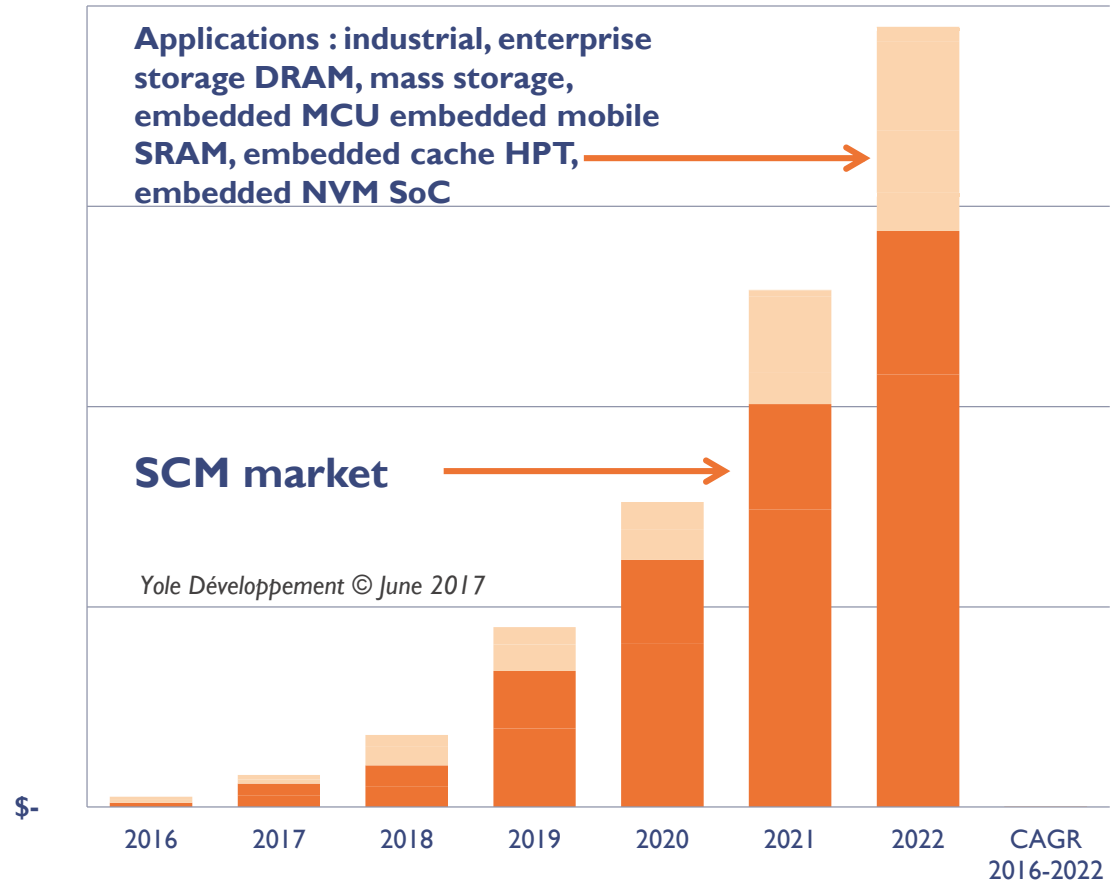
EMERGING NVM MARKET - FORECAST BY APPLICATIONS

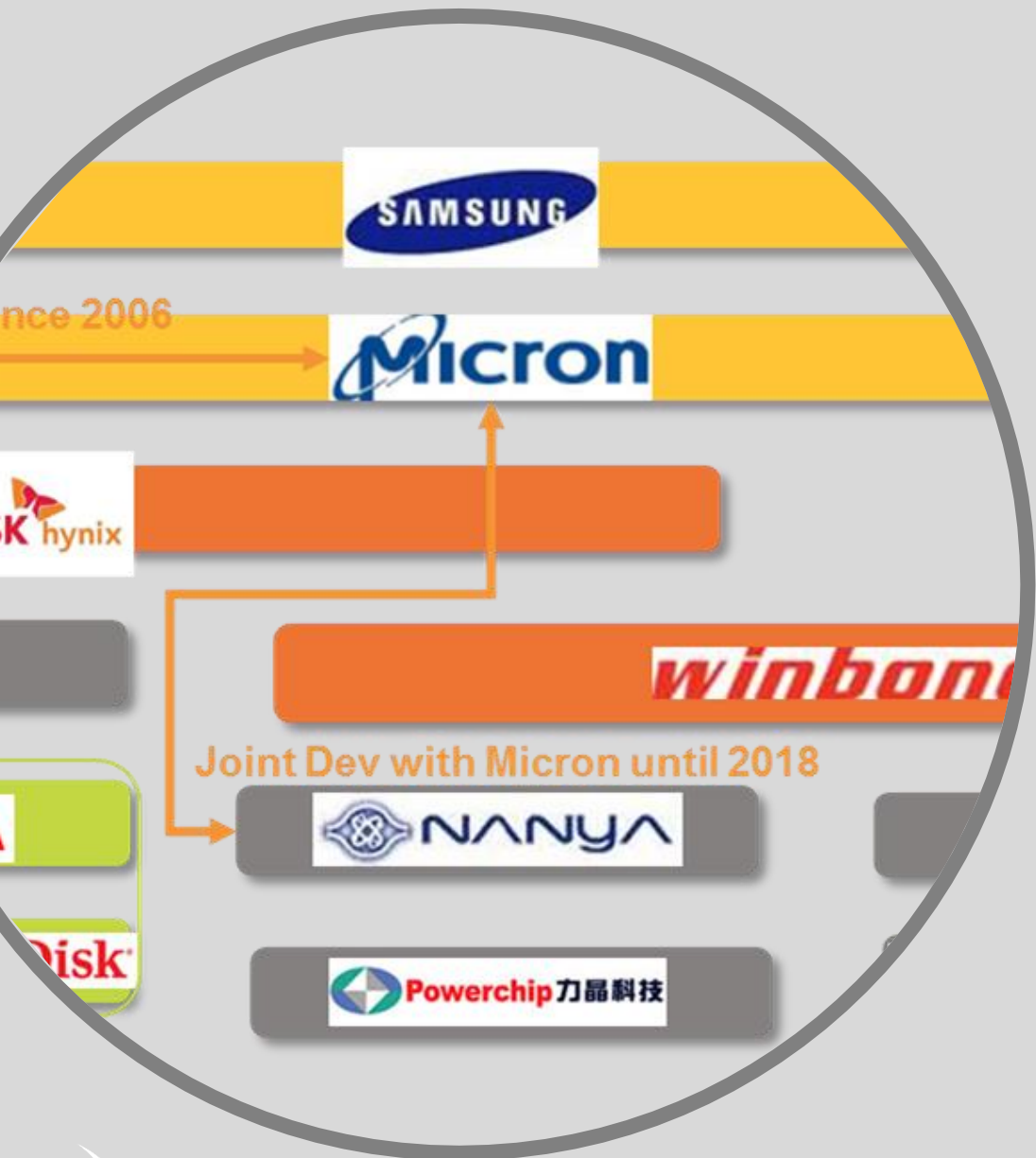
2016 - 2022 (in \$M)



SCM will drive the stand alone and the overall emerging NVM market growth

Emerging NVM Market Forecast by Application (in \$M)



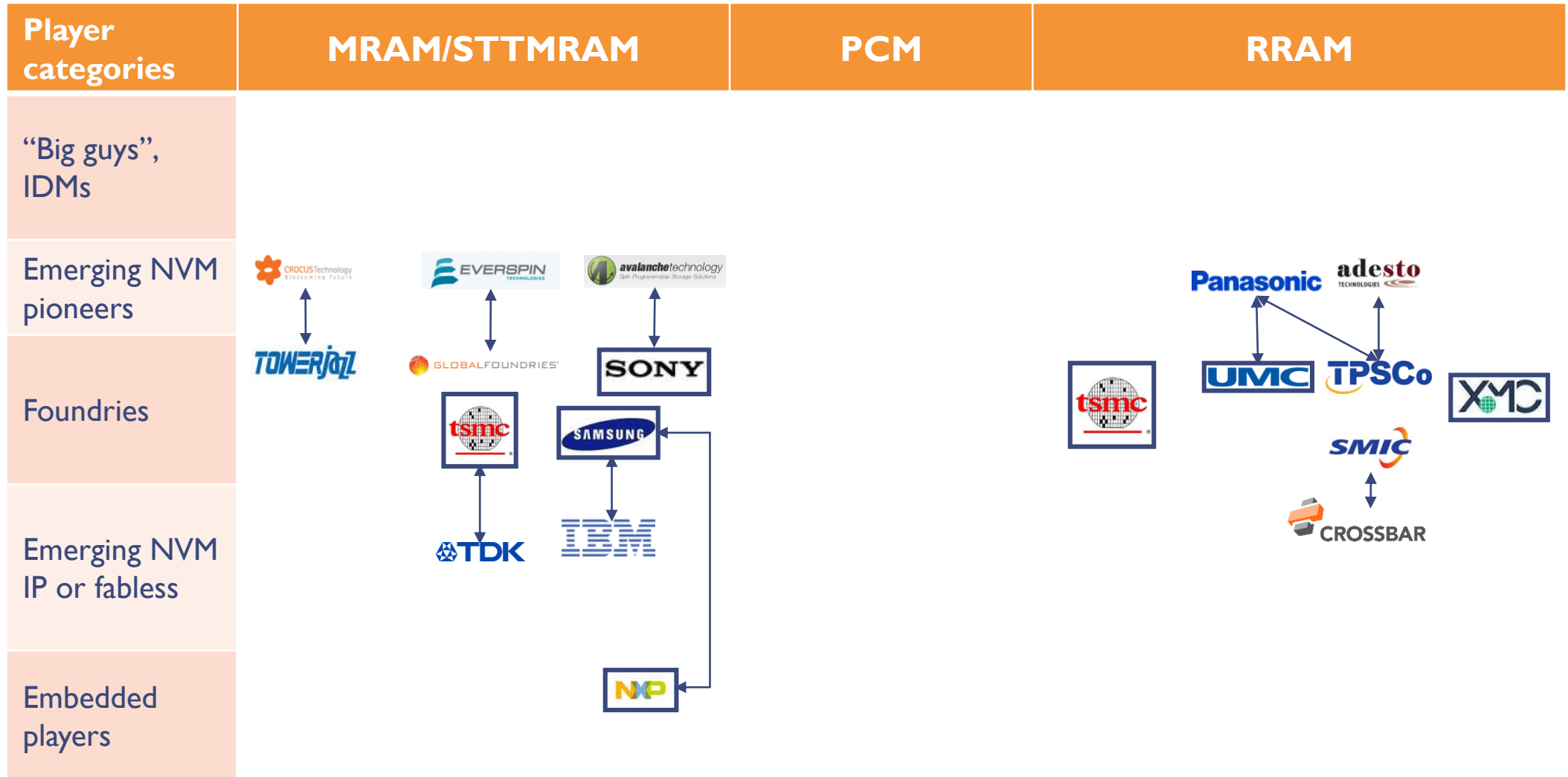


Emerging NVM market players

EMERGING NVM - KEY INDUSTRIAL PLAYERS

Foundries collaboration with eNVM players for embedded application

All top logic foundries (TSMC, Samsung, Global Foundries etc) are collaborating with emerging NVM players for embedded application.



Recent new entrant

NOTEWORTHY NEWS SINCE ONE YEAR



• MRAM

- [GLOBALFOUNDRIES](#) introduced a scalable, embedded (eMRAM) on its 22FDX platform,
- [Spin Transfer Technologies](#), announced it has delivered 80nm samples of OST-MRAM devices to multiple customers in North America and Asia.
- [Everspin](#) files for an IPO, aims to raise \$45 million
- [IMEC](#) presented at IEDM, a 8nm p-MTJ device with 100 percent tunnel magneto resistance (TMR) and coercive field as high 1500Oe.
- [Avalanche Technology, Inc.](#), has entered into a manufacturing agreement with [Sony Semiconductor Manufacturing Corporation](#) to begin production on 300mm wafers.

• RRAM

- [Leti](#) and Israeli ReRAM start-up [Weebit Nano](#) are to collaborate to develop ReRAM memory technology based on silicon oxide (SiOx).
- [4DS Memory](#) announced that it developed working 40nm RRAM memory cells and raises AU\$4m. This was achieved in collaboration with [HGST](#), a subsidiary of [Western Digital](#).
- [Fujitsu Semiconductor](#) announced the launch of the 4 Mbit ReRAM, the world's largest density mass-produced ReRAM product. This is the first ReRAM product to be jointly developed with [Panasonic](#)
- [Panasonic Semiconductor Solutions \(PSCS\)](#) and [United Microelectronics \(UMC\)](#) have reached an agreement to jointly develop next-generation 40nm Resistive Random Access Memory (ReRAM) technology for mass production at UMC.
- [Rambus](#) Signs License Agreement with [Western Digital](#) for patented memory technologies, including high-speed interfaces, memory architectures, resistive memory and security technologies

• PCM

- [Intel](#) launched commercially its first solid-state drives using its 3D XPoint memory chips, getting a long-awaited foothold in a market between flash and DRAM

• NRAM

- [Nantero](#) announced the closing of an over \$21 million financing round. Nantero currently has more than a dozen partners and customers in the consumer electronics, enterprise systems, and semiconductor industries actively working on NRAM®.



General conclusions

Conclusions

Favorable factors are coming in place that will propel the emerging NVM business

What has changed now ?

- *Emergence of new storage class memory (SCM) business segment that will not substitute DRAM & NAND but it's additional memory hierarchy in system architecture to reduce latency. SCM particularly enterprise storage is a fast-growing market.*
- *Big players stand alone players like Intel introducing PCM based 3D XPoint memory in market in 2017 for SCM application. Micron will introduce 3D XPoint memory product by end of 2017*
- *Big foundries like TSMC, Global Foundries, UMC, Samsung, and SMIC are entering the emerging NVM memory business with introduction of MRAM & RRAM technologies. Emerging NVM is a good opportunity for foundries to significantly grow their memory business as these are CMOS compatible technology*
- *Investors are still upbeat about the emerging NVM business which can be evidenced by >\$100M funding in 2016*
- *Key application that will drive the embedded market initially is eflash MCU followed later by SRAM & NVM SoC.*



Thank you for your attention !

Any questions ?

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